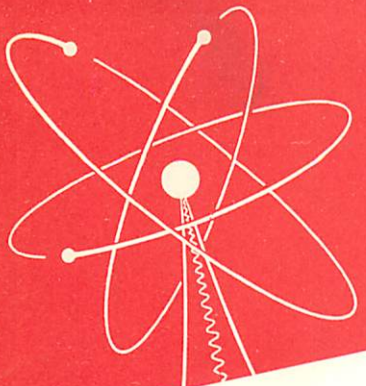

HIGH VOLTAGE SUPPLIES

Lesson T2C-13A

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DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

T2C-13A

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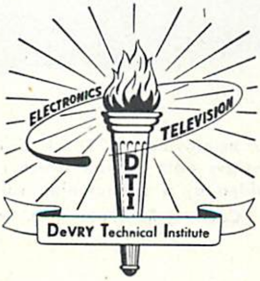

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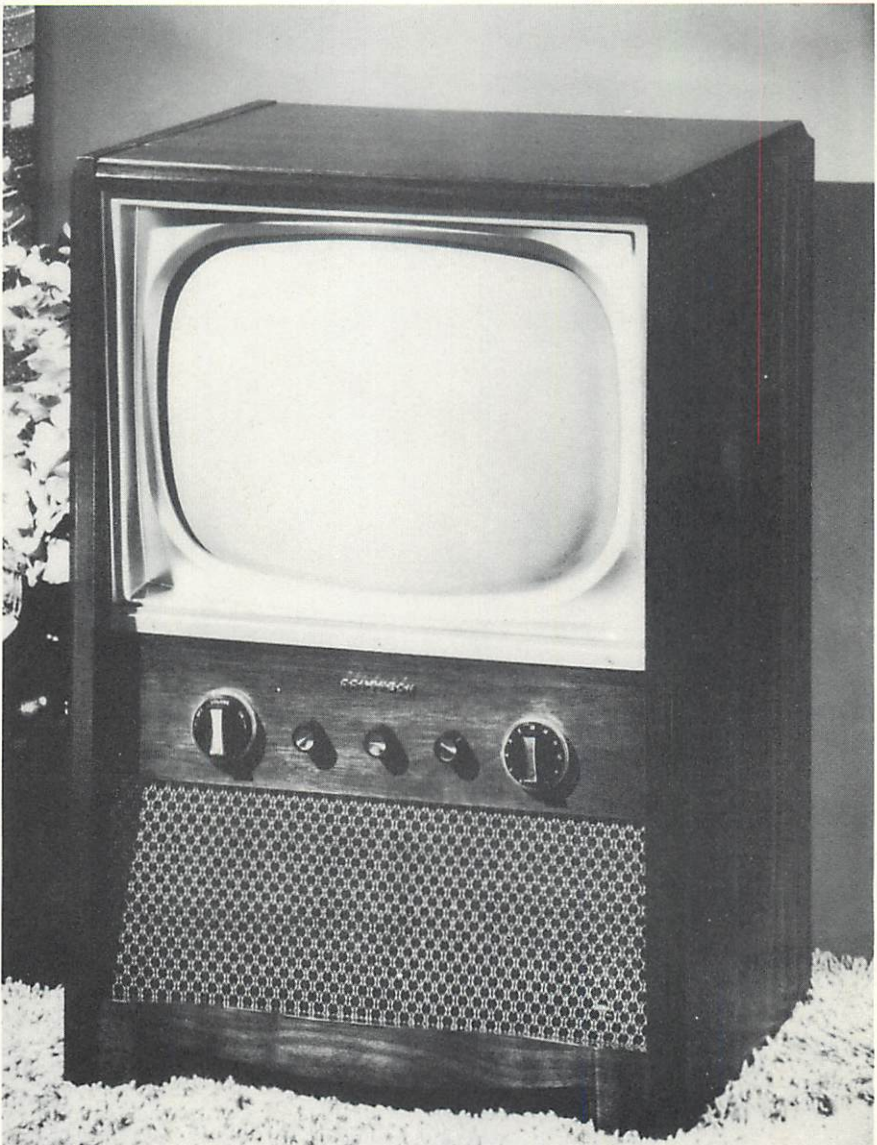

Console model television receiver employing a 21-inch picture tube, the most popular screen size. To produce the necessary light on the screen, the anode is operated at a high positive potential provided by a special high voltage generating circuit.

Courtesy Raytheon Mfg. Co.—TV and Radio Operations

HIGH VOLTAGE SUPPLIES

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Never be hurried, do everything tranquilly and with a restful spirit; do not lose your inward peace for anything whatsoever, not even when all seems going wrong.
—Francis de Sales

HIGH VOLTAGE SUPPLIES

TELEVISION RECEIVER VOLTAGE REQUIREMENTS

Depending upon their size and design, television receivers utilize anywhere from about 120 to 200 watts from the 117 volt power line in the case of the black and white receivers, while color receivers require between 400 and 600 watts. One or more power supply circuits convert the alternating voltage from the line to a direct voltage of from 250 to 400 volts as required. In the output circuit of this power supply, a voltage divider system provides the various voltages needed such as 300 volts, 220 volts, 150 volts, etc. Used for the plate and screen circuits of most of the tubes, these voltages are low compared with the several kilovolts applied to the anode of the picture tube. Hence, this supply is called the low voltage supply. In addition to the various "low" direct voltages for the plates and screens, the low voltage supply provides the alternating voltages required to operate the heaters of the tubes.

The picture tube anode receives its voltage from a separate circuit called the high voltage supply which obtains its input from the horizontal deflection output circuit. In turn, the horizontal output circuit obtains its operating voltages from the low voltage supply in series with the B+ boost supply. Often, this series combination of supplies provides operating voltages for tubes in other stages of the receiver, and for the No. 2 grid of the picture tube. This lesson describes the circuits and operation of the various types of high voltage supplies.

HIGH VOLTAGE GENERATING METHODS

Since the advent of commercial television, a number of methods have been devised for obtaining the high voltage required by the picture tube anode. Depending upon the size of the screen, and also upon the tube type within each size category, anywhere from 12,000 to 30,000 volts are needed by the anode for proper operation of the picture tube. Fortunately, so far as receiver power consumption is concerned, the required anode current is between 100 and 200 microamperes.

The earliest television receiver models contained high voltage supplies designed on the same plan as the power supplies employed in broadcast radio receivers. That is, a power transformer stepped up the 60 cycle line voltage from the 117 volts across the primary to about 4400 volts across the secondary. The secondary winding applied this stepped up voltage to a rectifier tube in series with a capacitor. Conduction of the rectifier charged the capacitor to the peak of the applied voltage, to obtain a direct voltage of 1.4×4400, or about 6000 volts. To form a voltage doubler circuit, another rectifier and capacitor were connected so that they were in series with the transformer secondary and the first capacitor. Thus, conduction of the second rectifier charged the second capacitor to a total of 12,000 volts, which became the output of the supply.

This 60-cycle type high voltage supply had the advantage of very good regulation, provided a sufficient bleeder current was employed. Another characteristic of this circuit was that, because of its basic design, it was capable of supplying a large output current, if called upon to do so. As mentioned, the average current required by the picture tube anode is only 200 microamperes or less. Therefore, it is not economical to employ power supply components capable of providing several hundred times the current needed for the high voltage anode circuit. Furthermore, when the high voltage supply is able to supply a large current, the television receiver is a very dangerous device to service. Because of these disadvantages of the 60-cycle type high voltage supply, engineers sought other means for obtaining the picture tube anode voltage.

One general arrangement developed is that in which the output of an oscillator is increased in amplitude and then rectified to provide the required high voltage. This system has been employed in three forms.

In the first, a blocking oscillator pulse generator is operated at

The type 6BQ6GT beam power amplifier, with plate cap at the top, is especially designed for service as the output amplifier of the horizontal deflection circuit.

Courtesy CBS

the line scanning frequency of 15,750 cps. The pulse voltage output is amplified and then coupled through a step-up transformer to the rectifier circuit. Conduction of the rectifier charges a capacitor to a direct voltage approximately equal to the pulse peak. This capacitor voltage then becomes the output high voltage of the supply. In this system, the blocking oscillator is operated so that it does not oscillate unless a triggering pulse is applied to its grid circuit. The triggering signal usually is obtained from the output of the horizontal deflection circuit. Should the deflection circuit fail for any reason, no triggering signal is applied to the high voltage supply blocking oscillator, and the high voltage is no longer generated. This arrangement protects the screen of the picture tube from burns in the event of horizontal sweep circuit trouble. Because the waveform of the blocking oscillator output is a pulse, this voltage supply arrangement is called a pulse type high voltage supply.

The second form of oscillator-rectifier supply circuit is a pulse type also. In this case, a free-running blocking oscillator operates at a frequency of approximately 1000 cycles per second. Again, the oscillator pulse output is applied to a voltage amplifier stage, the output of which is stepped up by a transformer and then applied to the rectifier circuit. To further increase the magnitude of the high voltage supply output, the rectifier circuit may consist of a voltage doubler or tripler.

In the third form, the one used most often of the three, an r-f oscillator provides a sine wave voltage which is stepped up by a transformer and then rectified. Using this method, high voltage supplies have been designed which are capable of delivering up to 1 milliampere of current at from 1,000 to 50,000 volts.

As explained in the lesson on sweep output amplifiers, when the current changes rapidly in the deflection coil during the retrace or flyback interval, the magnetic deflecting field collapses into the coil quickly to induce a back emf across the coil. This emf is applied to the secondary of the output transformer. As this transformer has a step-down turns ratio, going from primary to secondary, the turns ratio is step-up in the case of voltage coupled in the other direction. That is, the emf applied by the deflection coils to the secondary is stepped up to appear as a higher voltage across the primary. This fact forms the basis upon which the "flyback" type of high voltage supply has been developed.

Because of the higher frequency at which the horizontal deflection circuit operates, the emf produced in the horizontal coil during flyback is much greater than that produced across the vertical coil. Therefore, the horizontal coil is employed as the source of voltage for the flyback high voltage supply circuit. The stepped up pulse across the output transformer primary is applied to a rectifier tube, conduction of which charges a series capacitor to the peak of the pulse.

FLYBACK HIGH VOLTAGE SYSTEMS

Although all of the high voltage generating methods mentioned have been used in the various makes and models of television receivers, practically all models employ the flyback arrangement at the present time. The basic flyback circuit is shown in Figure 1. The driver tube V$_1$ is the output amplifier of the horizontal sweep circuit. T$_1$ is the horizontal output transformer on which secondary winding L$_4$ connects to the horizontal deflection coils. During the portion of the forward sweep period that V$_1$ is conductive, its steadily rising plate current produces an expanding magnetic field about primary winding L$_2$. This field induces a voltage across L$_4$ which produces a linear rise of current in L$_4$ and the deflection coils.

During the flyback interval, V$_1$ is cut off by the negative voltage on its control grid, and there is no plate current in L$_2$. The deflection field collapses rapidly into the deflection coils, and the voltage thus induced is applied to winding L$_4$. Now, transformer T$_1$ serves a second purpose which is to step up the voltage applied to it by the deflection coils. For this action, L$_4$ is the primary, while the secondary consists of the total winding, L$_1$ + L$_2$. Since the secondary (L$_1$ + L$_2$) contains several times as many turns as primary L$_4$, the peak voltage induced in the secondary by transformer action is equal to several times the peak voltage produced across the deflection coils by the falling current. In various receivers, the collapsing deflection field induces a back emf of 1200 volts or more, and transformer T$_1$ steps this voltage up to the 12 kv or more required by the anode of the picture tube.

For replacement or conversion purposes, horizontal output transformers, yokes, etc., designed to match each other, can be obtained in kit form.

Courtesy Merit Coil & Transformer Corp.

Assume the voltage pulse E_1, produced across L_1 and L_2, makes the upper end of L_1 positive with respect to the lower end of L_2. Since L_2 connects to the low voltage supply positive terminal, the output of this supply E_2 and part of the positive pulse E_1 are applied series aiding to the plate of rectifier tube V_2. With the plate of this tube positive due to these applied voltages, electrons flow from filament of V_2 to its plate, through L_1 and L_2 to B+ of the low voltage supply, from B− to the lower plate of C_1, and from the upper plate of C_1 to the filament of V_2. This electron flow charges C_1 to the polarity indicated, and to a voltage equal to the sum of the pulse peak across L_1 and L_2 and the low voltage supply output. That is, neglecting the relatively small voltage between the cathode-plate of V_2 the total voltage E_{C_1} is equal to $E_1 + E_2$. As indicated, the voltage across C_1 is applied to the anode of the picture tube.

The changing magnetic field about L_4 cuts transformer winding L_3 to induce the current required for the filament of V_2. Once C_1 is charged, the voltage across it remains nearly constant, since the only discharge path is the high resistance circuit of the picture tube anode.

At all times, the V_2 filament is positive with respect to ground by the amount of the voltage across C_1. In the period between one retrace interval and the next, the V_2 plate is at approximately the same positive voltage as the plate of V_1, since they connect through L_1. At this time, the V_2 filament is more positive than the plate, and the tube is nonconductive. The only time V_2 conducts to replenish the charge on C_1 is on the peak of the positive pulse produced across L_1 and L_2 during retrace. Therefore, these brief intervals are the only time V_2 requires filament power. Thus, only the rapid change of flux in T_1 during flyback produces sufficient current in L_3 for proper operation of the V_2 filament.

Horizontal output circuits employ either of two methods for coupling the driving voltage from the plate circuit of the amplifier or driver tube to the deflection coils. The essential difference is in the type of output transformer. However, the difference in transformer types necessitates differences in the connections of the damper tube, linearity coil, and other components which make up the complete circuit. Both methods have been described in a previous lesson. One is that in which the primary and secondary are separate windings, as in Figure 1. For convenience, we shall designate this arrangement as the transformer system. The other arrangement, known as the direct drive or high efficiency system, employs a single winding as an auto-transformer.

Transformer System

A flyback high voltage supply circuit using the transformer system is illustrated in Figure 2. Here, the pentode tube V_1 is the horizontal deflection circuit output amplifier, V_2 the high voltage rectifier, V_3 the damping tube, and V_4 the picture tube. The output transformer contains the tapped primary L_1 and secondaries L_2 and L_3. L_2 supplies sawtooth current through L_4 and C_4 to the horizontal deflection coils, while damping tube V_3 prevents oscillation in this circuit. The filter composed of C_2, L_5, and C_3, and tube V_3 form the boost voltage circuit.

Briefly reviewing the boost circuit action, when the upper end of winding L_2 is positive, voltage E_{L_2} is applied series-aiding with the low-voltage supply output, causing conduction of V_3 so that C_3 is charged to the sum of these applied voltages. The voltage E_{C_3} is applied through L_5 to charge C_2. E_{C_2} supplies the plate circuit of amplifier tube V_1.

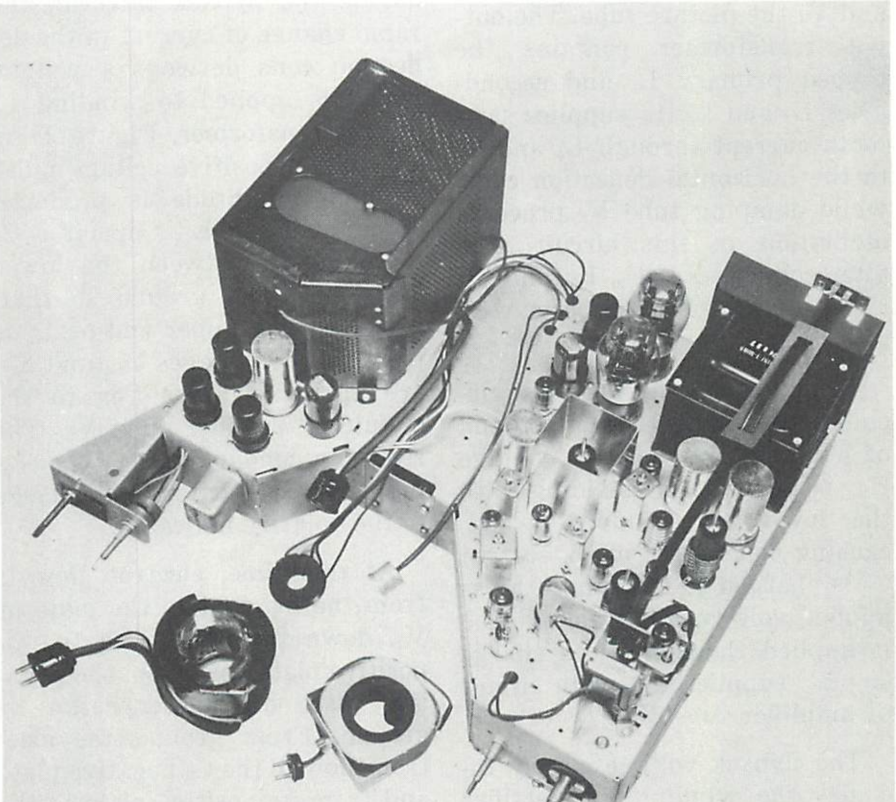
The flyback voltage supply includes the winding L_1, rectifier tube V_2, and the filter consisting of C_6, R_4, and C_7. The output filter capacitor, indicated as C_7, is formed by the capacitance between the inner and outer conductive coatings of picture tube V_4. As shown, R_4 connects to the internal coating which is joined to the anode inside of the tube. Thus, this coating serves as the positive plate, the glass envelope as the dielectric, and the grounded external coating as the negative plate of the output filter capacitor.

As explained for Figure 1, during the flyback interval, the rapid change of current in the deflection coils develops a voltage which is applied to winding L_2 of the transformer, Figure 2. As a result, a positive voltage pulse of high amplitude is produced across winding L_1. Capacitor C_2 is connected between the lower end of L_1 and ground so that, whenever the upper end of L_1 is positive, the voltages E_{L_1} and E_{C_2} are applied series-aiding to the circuit of rectifier tube V_2. The resulting conduction of V_2 causes input filter capacitor C_6 to charge to the polarity indicated.

At this time, electron flow is from the filament to the plate of V_2, down through L_1 to the C_2 positive plate, and from the negative plate of this capacitor to ground. From ground the electrons flow to the C_6 negative plate and from its positive plate to the filament of V_2. This action charges C_6 to the sum of the peak voltage across L_1 and E_{C_2}. Capacitor C_7 charges through R_4 to the same voltage as C_6, and thus the high voltage output is applied directly to the V_4 anode.

Ordinary types of high voltage rectifier tubes require a comparatively high filament power and are not designed otherwise for high frequency operation. Requiring only one-quarter watt of heater power, special rectifier tubes have been developed, such as the 1B3GT, the 1X2, and the 1V2 for use in circuits where limited power is available. Any one of these may be used as V_2 in the circuit of Figure 2.

As explained for the similar arrangement of Figure 1, the filament voltage for the V_2 diode is obtained by means of a one or two turn winding L_3 placed in the



Television receiver chassis with picture tube removed. The horizontal sweep output circuit components and the high voltage rectifier tube are enclosed by the black metal housing shown at the upper center.

Courtesy Mars Television Inc.

magnetic field of the deflection transformer. The location of this loop is somewhat critical because it must be placed so that it will develop a voltage which lies within the rated tolerance range of the V_2 filament. Series resistor R_2 serves to limit the current and prevent excessive filament heating.

Because of the high operating potentials on the V_2 electrodes, its socket must be placed on an insulated mounting that will prevent "arc-over", and all leads and connections must be kept at least 1 inch away from any grounded point. Also to avoid "corona" discharges into the atmosphere, the conductors must have large diameters, and the edges of the various components must not be sharp, but have rounded corners.

Capacitor C_4 is a d-c blocking capacitor which is included so that only the alternating deflection current is carried by the coils.

Connected across V_3, resistor R_3 conducts in parallel with the damper tube. This resistor provides additional damping action, and prevents excessive differences in potential between the plate and cathode of V_3.

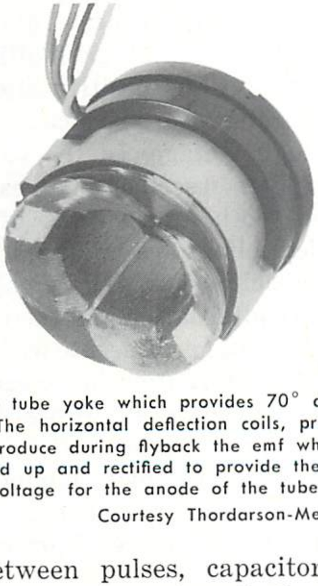
Voltage Multiplier

In some applications the required voltages are higher than the output of a circuit like that of Figure 2, and voltage multiplier systems employing two or more rectifiers are needed. Figure 3 shows an arrangement in which three diodes, V_2, V_3, and V_4 are connected as a voltage tripler. V_1 is the horizontal sweep amplifier with its plate connected to the primary L_1 of output transformer T_1. As indicated, secondary L_5 is connected to the horizontal deflection coils, while individual windings L_2, L_3, and L_4 supply the filament voltage for the rectifier tubes.

As indicated in the Figure, the voltage across L_1 consists of high amplitude positive pulses with low amplitude negative alternations. In this voltage multiplier circuit, only the positive alternations are used to produce a rectified high voltage. In the voltage multipliers described in an earlier lesson, both alternations of the applied voltage are employed, with one capacitor charging during the positive alternation and then adding its voltage in series with the negative alternation to charge the second capacitor, etc. However, in the circuit of Figure 3, all the rectifier tubes conduct during the positive pulses and none conduct during the negative alternations across L_1.

The low voltage supply is in series between the lower end of L_1 and ground, and during the positive pulse across L_1, rectifier

V_2 conducts, charging C_1 to the polarity indicated. For this action, electron flow is from the filament to the plate of V_2, through L_1 to B+, and through the low voltage supply to ground. From ground electrons flow to the negative plate of C_1 and from its positive plate to the V_2 filament. The positive pulses occur at the horizontal scanning frequency, therefore, C_1 discharges only slightly between pulses and is recharged by each succeeding pulse so that its charge is maintained practically constant and approximately equal to the sum of the B+ and pulse voltages.



Picture tube yoke which provides 70° deflection. The horizontal deflection coils, protruding, produce during flyback the emf which is stepped up and rectified to provide the high voltage for the anode of the tube.

Courtesy Thordarson-Meissner

Between pulses, capacitor C_1 slowly discharges into C_4 through the high resistance R_1. The simplified diagram of Figure 4A shows the C_1 discharge circuit which includes the low voltage power supply, transformer winding L_1, capacitor C_4, and resistor R_1. To charge C_4, electrons flow from the C_1 negative plate to ground, and from ground to the negative terminal of the low voltage supply. From the positive terminal of this supply they travel through L_1 to the C_4 negative plate, and from the positive plate of C_4 the path is completed through R_1 to the positive plate of C_1.

Although the low voltage supply output E_{LV} is in series opposition to the charge on C_1, the magnitude of E_{C_1} is much greater than E_{LV}. Therefore, the electron flow takes place as described, and C_4 is charged to the polarity indicated and to a voltage equal to E_{C_1} minus E_{LV}. E_{C_1} is equal to the L_1 pulse voltage plus E_{LV}, therefore, the charge voltage E_{C_4} will be equal to the peak of the L_1 positive pulses. Due to the high resistance in the C_1 discharge path, C_4 charges over a relatively long period of time during which the charge on C_1 is maintained by the succeeding L_1 pulses as explained.

With C_4 charged to the polarity indicated in Figure 3, its voltage adds in series with the L_1 pulses to produce conduction of diode V_3, and this action charges capacitor C_2 to the polarity shown. Electron flow is from the filament to the plate of V_3, to the positive plate of C_4, and from the negative plate through L_1 to B+. The path is continued through the low voltage supply to ground, from ground to the negative plate of C_1, and from the positive plate of C_1 to the negative plate of C_2. From the positive plate of C_2 the path is completed to the V_3 filament.

For simplicity, the various components included in the C_2 charging circuit are shown in the simplified diagram of Figure 4B. Here, voltage E_{C_4}, the pulse e_{L_1}, and the output of the low voltage supply are applied series-aiding to the V_3 circuit and the rectified current causes capacitors C_1 and C_2 to be charged in series to E′ which is equal to the total of the applied voltages. However, since C_1 has been charged already to a voltage equal to $e_{L_1} + E_{LV}$, the net voltage causing conduction of V_3 is the charge on C_4. Therefore, C_2 is charged to a voltage equal to E_{C_4}.

During the intervals between the e_{L_1} positive pulses, C_2 discharges through R_1 and R_2 into C_5 as shown in the circuit of Figure 4C. Here, electrons leave the C_2 negative plate and flow through R_1 to the C_5 negative plate. From the C_5 positive plate the flow is through R_2 to the C_2 positive plate. As this action continues for a series of cycles, the charge on C_5 becomes approximately equal to that of C_2.

Referring to the connections and polarities of Figure 3, the L_1 positive pulses, the charge of C_4 and the charge of C_5 are series-aiding to cause conduction of V_4 and thus charge capacitor C_3 to the indicated polarity. As shown in the circuit of Figure 4D, the series aiding voltages, E_{C_5}, E_{C_4}, e_{L_1} and the low voltage supply output are applied to diode V_4 and capacitors C_1, C_2, and C_3 which are charged so that their total voltage, designated in the Figure as E″, is equal to the sum of the four applied voltages. Since the charges already existing on C_2 and C_1 are equal to the total of E_{C_4}, e_{L_1}, and E_{LV}, the charge, E_{C_5}, is the net voltage causing current in the V_4 circuit. Therefore, C_3 is charged to a voltage equal to E_{C_5}.

In Figure 3, the high voltage supply output is taken from series-connected capacitors C_1, C_2, and C_3 so that the voltage applied to the picture tube anode is approximately equal to three times the pulse peak plus that of the low voltage power supply. Due to the picture tube electron beam only, the current drain on the high voltage supply is extremely low, and the charges on these capacitors are maintained practically constant by the recharging action of the positive pulses across L_1.

Direct Drive System

The flyback voltage supply arrangement in a receiver in which the horizontal deflection circuit is a direct drive system is illustrated in Figure 5. Taps on the autotransformer winding of T_1 separate this winding into three sections. The plate of horizontal output tube V_1 connects to the tap which separates section L_1 from L_2. Sections L_2 and L_3 are separated by the tap which connects to the cathode of V_4 and one terminal of the deflection coils.

A 1B3-GT tube, used in many television receivers to rectify the high voltage produced during horizontal retrace. This voltage is applied to the second anode of the picture tube.
Courtesy Radio Corporation of America

During the portion of the cycle that the output of V_1 drives the deflection coils, L_2 and L_3 serve as the primary of the autotransformer while L_3 alone is the secondary. During the flyback or return sweep interval when V_1 is cut off, the deflection coils apply a voltage to L_3. At this time, L_3 is the primary, while L_1, L_2, and L_3 together serve as the secondary to apply a high amplitude positive voltage pulse to the plate of high voltage rectifier V_2.

The boost voltage circuit consists of damper tube V_4 and capacitor C_2. During the first part of the forward sweep, the voltage across the deflection coils is greater than that across C_2, and has a polarity such that the upper end of the coils is negative. Thus, the cathode of V_4 is more negative than the plate, which connects through fuse F_1 to the negative plate of C_2. As a result, the damper tube conducts, increasing the charge on C_2. Electrons flow from the cathode to the plate of V_4, through F_1 to the negative plate of C_2, and from the positive plate of this capacitor through the deflection coils to the V_4 cathode.

Thus, the large positive pulse across L_1, L_2, and L_3, the voltage across C_2, and the +265 volt output of the low voltage supply are all applied in series to the plate of rectifier V_2 during the flyback interval. These applied voltages produce electron flow from the filament to the plate of V_2, through L_1, L_2, and L_3 to the upper plate of C_2, from the lower plate of C_2 to B+, from B− to the grounded outside coating of V_3, and from the inside coating of V_3 through R_4 to the filament of V_2. This pulse of current charges capacitance C_3 to approximately the total of the three applied voltages, with the inside coating positive with respect to ground. Current exists only until C_3 regains the small charge it lost since the charging pulse of the previous cycle. Therefore, the current pulse is very small, and does not discharge C_2 by any appreciable amount, since the capacitance of C_2 is .1 μf compared with the 500 to 750 $\mu\mu$f of C_3.

R-F HIGH VOLTAGE SYSTEM

The circuit diagram of an r-f type of high voltage supply is shown in Figure 6 where tube V_1 is a high transconductance pentode connected in a tuned plate type oscillator circuit. The tuned plate circuit consists of coil L_1 and variable capacitor C_1, while the feedback to the grid circuit is supplied by the tickler coil L_3. Bias is developed by grid leak resistor R_1 and capacitor C_4.

L_1 is the primary and L_2 the secondary of a voltage step-up transformer. Applied to rectifier V_2, the secondary high voltage causes diode current which charges capacitors C_2 and C_3 to a high direct voltage.

Coupled to L_1, coil L_4 provides the V_2 filament current. Connected to B+ of the low voltage supply, the RFC aids bypass capacitor C_5 in preventing the high frequency energy from being coupled to the other sections of the receiver.

The 1X2A is another tube type commonly employed as the rectifier in television receiver high voltage supply circuits.

Courtesy CBS

Employing self excitation with feedback from the primary winding, conventional oscillator circuits have an unstable tuning characteristic. Therefore, for greater stability, the oscillator of Figure 6 has the grid tickler, L_3, coupled to the secondary L_2. For the best compromise between stability, physical size, and high voltage requirements, the oscillator frequencies range from about 50 to 500 kc and L_2 is designed to resonate with its distributed capacitance plus the V_2 interelectrode capacitance to a frequency within this range. These supplies operate at the lower frequencies to prevent "arc-over" and to reduce power loss.

The transformer primary and secondary coils, L_1 and L_2, are tightly over-coupled in order to improve the stability of the d-c output voltage. To maintain good voltage regulation and efficiency under full load conditions, at least 20 times critical coupling is necessary, although this arrangement reduces the voltage step-up to about half of the maximum obtainable.

In the voltage supply circuit of Figure 6, the high voltage output can be varied by means of the tuning capacitor C_1. To obtain the most stable operation of the oscillator, C_1 is first adjusted to the maximum output voltage, after which the capacitor is adjusted to a slightly lower capacitance.

The maximum power output of the oscillator is very limited; therefore, to supply filament current as shown, a rectifier tube which requires a very small filament power such as a 1B3GT, 1X2, or 1V2 must be used as V_2.

Because of the high frequencies employed, adequate filtering is afforded by relatively low filter capacitance. Typical values for C_2 are from .01 μf in the lower voltage circuits to about 300 $\mu\mu$f in the supplies designed for highest voltage outputs. Also, due to the high frequencies used, coupling through the low voltage supply to the other receiver circuits is negligible because bypass capacitor C_5 provides a low reactance r-f path to ground.

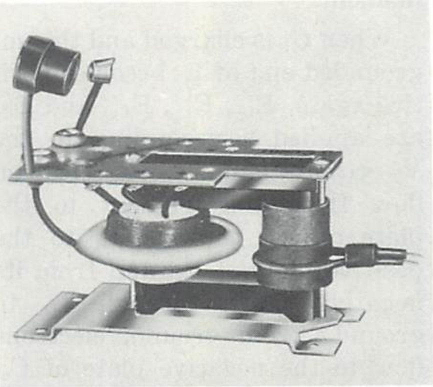
An advantage possessed by the r-f high voltage supply is that body contact with any high voltage point lowers the Q of the tuned circuits to such a value that oscillation ceases immediately. The only charge then available is that which is stored in the filter capacitors. Because of the low capacitance, this stored charge is small, and therefore, the circuit is considered a "safe" high voltage supply.

A number of variations of the basic circuit of Figure 6 are used in commercial applications. Figure 7 shows one variation. Here, the two oscillator tubes, V_1 and V_2, are operated in parallel, coil L_1 and capacitor C_{12} form the tuned-plate circuit, and feedback is obtained by means of the grid circuit tickler coil L_2. Grid leak bias is produced across R_5 and C_4. R_3 and R_4 limit the grid currents to safe values. R-f chokes L_4 and L_5 are employed in parallel to carry the total d-c of the V_1 and V_2 plate circuits. These chokes and C_1 prevent r-f plate currents from being carried by the power supply. R_6 and R_7 are parasitic oscillation suppressors.

Coils L_1 and L_3 form the primary and secondary of the voltage step-up transformer. The r-f across L_3 is applied to a voltage tripler circuit containing V_3, V_4, and V_5 and capacitors C_6, C_7, and C_8.

From the positive plate of C_8, the supply output is applied through filter resistor R_8 to the second anode of the receiver picture tube. Coils L_6, L_7, and L_8 are low voltage secondaries for supplying the required rectifier tube heater currents, and also to provide a slight increase in the voltage applied to the rectifier circuits. These coils are coupled to L_3 so that when the ungrounded end of L_3 is positive, the ends farthest from the tube filaments are positive also, thus making the voltages series-aiding.

Since the voltage across L_3 has symmetrical wave-form, a conventional voltage multiplier circuit is employed. During the alternations that the ungrounded end of L_3 is positive V_3 is conductive and C_6 charges to the polarity indicated and to the peak value of E_{L_3} plus E_{L_6}, about 10,000 volts. Electron flow is from the filament to the plate of V_3 and through L_3 to ground. From ground, electrons flow to the negative plate of C_6 and from its positive plate through L_6 to the V_3 filament.



Horizontal output, or flyback, transformer. Notice the wax tire covering the tertiary winding. Extending from this winding, the lead with the large cap connects to the plate of the high voltage rectifier. The other cap connects to the plate of the horizontal output tube. The single loop is the secondary which supplies current to the filament of the high voltage rectifier.

Courtesy Chicago Standard Transformer Corp.

During the alternations that the ungrounded end of L_3 is negative, voltages E_{L_3} and E_{L_6} in series with E_{C_6} cause conduction of V_4, which charges C_7 to the polarity indicated, and to the sum of E_{C_6} and the peak of E_{L_3} and E_{L_6}, or about 20,000 volts. Electron flow is from the filament to the plate of V_4, through L_6 to the positive plate of C_6, and from its negative plate to ground. The path is completed from ground through L_3 to the negative plate of C_7 and from its positive plate to the V_4 filament.

When C_7 is charged and the ungrounded end of L_3 becomes positive again, E_{L_3}, E_{L_7}, E_{L_8}, and E_{C_7} are applied series-aiding to the V_5 circuit, and cause electron flow from the filament to the plate of V_5, through L_7 to the positive plate of C_7, and from its negative plate through L_3 to ground. From ground, electrons flow to the negative plate of C_6, from its positive plate to the negative plate of C_8, and from the positive plate of C_8 through L_8 to the V_5 filament. This charges C_8 to the polarity indicated, and although E_{C_7} plus E_{L_3}, E_{L_7}, and E_{L_8} equals 30,000 volts, the already existing charge of 10,000 volts on C_6 is series opposed to E_{C_7} and E_{L_3}. Thus there is a net voltage equal to 20,000 + 10,000 − 10,000, or 20,000 volts to cause conduction in the V_5 circuit, and C_8 charges to this value. For the supply output, the charges of E_{C_8} and E_{C_6} are series aiding, to provide a total output voltage of 20,000 + 10,000 or 30,000 volts.

At first thought, it might seem as though the charging action of C_8 would be short circuited by the conduction of V_3, since both V_3 and V_5 conduct on the positive alternation of E_{L_3}. However, as explained previously, once capacitors C_6, C_7, and C_8 are charged, each rectifier conducts only for the extremely short interval necessary to restore the corresponding capacitor charge lost due to current through the load.

For example, E_{C_6} places a positive bias on the V_3 filament so that this tube can conduct only during the instant that E_{L_3} plus E_{L_6} is greater than E_{C_6}. In like manner, V_4 can conduct only when E_{L_3} plus E_{L_6} plus E_{C_6} is greater than E_{C_7}, and V_5 conducts only when E_{L_3} plus E_{L_7} plus E_{L_8} plus E_{C_7} is greater than E_{C_6} plus E_{C_8}.

To provide a lower voltage for the first anode of the picture tube, a voltage divider consisting of resistors R_9 to R_{20} inclusive is connected across capacitor C_6. The first anode is connected to the slider on focus control potentiometer P_1 which, as shown, is connected across resistors R_{14} and R_{15} of the divider. This voltage is filtered by capacitors C_{10} and C_{11}, which are series connected to provide twice the working voltage of a single capacitor.

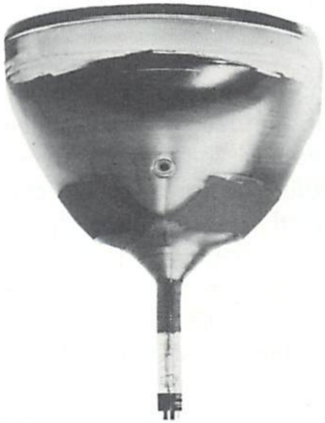
REGULATED HIGH VOLTAGE SUPPLIES

Although the exact details are beyond the scope of this presentation, in the television picture tube, the angle θ at which the beam is deflected is related to the anode voltage E_A as follows:

$$\theta = 1.7 \times 10{,}000{,}000 \frac{lB}{\sqrt{E_A}} \text{ degrees,}$$

where l is the length of the deflection coil and B is the flux density of the deflection field. This expression states that the amount of deflection, that is, the height or width of the raster, varies inversely as the square root of the voltage applied to anode. In effect, this relation merely states that the deflection angle becomes less as the anode voltage increases. The electron beam is "stiffer" and does not deflect as much with higher anode voltages. In normal operation, only the flux density should change during each sweep cycle. If the anode voltage changes also, it produces undesired changes in both the width and height of the picture.

In the picture tubes employed for monochrome (black and white) television, the beam current may be as high as 200 microamperes for average conditions of brightness. In color television three-gun picture tubes, the total beam current is about 600 microamperes. The path of the beam current is from the picture tube cathode to the screen by means of the electron beam, by secondary emission to the internal coating, to the positive terminal of the high voltage supply, through the supply circuits to ground, and from ground to the cathode of the picture tube.



A type 21AUP4B television picture tube, showing the internal and external conductive coatings which form the output filter capacitor of the high voltage supply, and the cavity which provides the means of connecting the high voltage lead from the supply to the inner coating of the tube.

Courtesy Westinghouse Electric Corp.

As with other voltage supplies, the high voltage supply action charges an output filter capacitor, and the load discharges this capacitor. To maintain a constant voltage on the capacitor, it must be recharged by the supply circuit as much as it is discharged by the load. In this case, the "load" is the beam current of the picture tube. The voltage across the high voltage supply filter capacitor is the operating voltage applied to the picture tube anode. In normal operation, the greater the beam current, the greater the tendency to discharge the filter capacitor, thus reducing the voltage applied to the anode of the picture tube. Conversely, the high voltage applied to the anode is higher when the capacitor is discharged less by a smaller beam current.

Applied to the grid or cathode of the picture tube, the video signal varies the beam current to provide the brightness changes required to reproduce the image on the screen. In this way, the normal operation of the picture tube causes the beam current to vary above and below the average value. As explained above, when the beam current increases, there is a decrease in the voltage applied to the anode of the picture tube. This action causes the picture to increase in size. On the other hand, a decrease in beam current increases the anode voltage and the picture then decreases in size. Thus, video signal variations cause anode voltage variations which, in turn, result in corresponding variations of picture width and height.

Picture size changes are detected most easily by noting the changes in position of the edges of the raster. However, in commercial television receivers, this means of determining such changes is not available to the viewer because the edges of the raster are out of sight behind the mask. Also, the normal studio techniques require frequent movement of the camera toward and away from the subject, and this action results in considerably greater changes in image size than those caused by anode voltage variations. Therefore, in the case of black and white television, the quality of high voltage supply regulation is unimportant, within reasonable limits.

In color television, the situation is different. The color picture tube contains three electron guns with a total beam current three times that in the black and white picture tube. Carried by the high voltage supply, this total beam current causes greater variations in the output voltage of the supply. Also, for proper operation of the color picture tube, the three beams approach each other, or converge, so that they meet at a point near the screen. To cause this action, a voltage called the "convergence voltage" is applied to an electrode in the picture tube. The convergence voltage is obtained from the receiver high voltage supply. Therefore, if the output voltage of this supply varies, improper convergence action occurs in addition to the undesirable changes in width and height of the picture. Moreover, in color television receivers, the high voltage supply output voltage should not vary more than about 2%. For this reason, voltage regulation methods are used in the high voltage supplies of color receivers.

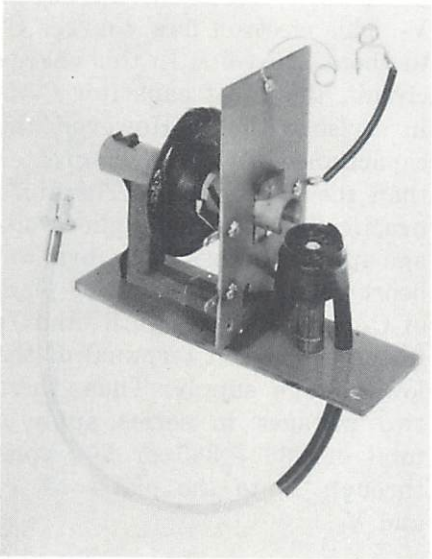
The Arvin Model 15-550KB color television receiver employs the high voltage supply circuit shown in Figure 8. Here, the horizontal amplifier consists of tubes V_1 and V_2 in parallel to provide sufficient current to the primary section of autotransformer T_1. By direct drive coupling, the lower section of the T_1 winding supplies alternating sawtooth current through C_3 and C_4 to the horizontal deflection coils.

For convenience in reference, the terminals and taps have been numbered on the T_1 winding, beginning at the top. During the forward sweep period, every point along this winding is negative with respect to point 5. A given point is more negative, the farther it is removed from point 5. Thus, connected to point 3, the damper tube cathode is more negative than it would be if connected to point 4.

During the first part of the trace period, the coils apply a voltage to the section between points 4 and 5 of the T_1 winding. Stepped up by autotransformer action, a higher voltage is produced between points 3 and 5 to cause conduction of V_3. Electrons flow through V_3 from cathode to plate, through one winding of T_2 and into the lower plate of C_6, out of the upper plate and into the negative plate of C_3, out of the positive plate, through T_1 from point 5 to point 3, and to the cathode of V_3. This electron flow charges C_3 to about 235 volts. In this charge circuit, the 25 μf capacitor C_6 is in series with C_3. However, the capacitance of C_6 is much greater than the .08 μf of C_3. Therefore practically all of the applied voltage appears across C_3 to form the boost voltage. The negative plate of C_3 connects through R_8 and T_2 to the +365 volt terminal of the low voltage supply. Thus, these two voltages in series apply a total of 235 + 365 or 600 volts through T_1 to the plates of V_1 and V_2.

During the flyback interval, when the deflection coils apply a voltage which makes point 4 positive with respect to point 5, all points along the T_1 winding are positive compared with point 5. Most positive of all, point 1 applies a high voltage pulse to the plate of rectifier V_4. The three rectifiers, V_4, V_5, and V_6 form a voltage multiplier which increases the level of the high voltage supply output to the 20 kv required by the anode of V_8.

Figure 9 illustrates the operation of the voltage multiplier. Here, the voltage across C_3 and the low voltage supply voltage are combined and represented as a 600 volt source. The section between points 1 and 5 of T_1 is connected between the plate of V_4 and the positive terminal of the 600 volt source, this terminal being the positive plate of C_3 in Figure 8.



Another horizontal output transformer. This assembly includes the socket for the high voltage rectifier. From the socket extends the heavily insulated lead which connects to the picture tube anode by means of the cavity connector in the bulb of the tube.

Courtesy Merit Coil & Transformer Corp.

When the retrace action causes the large positive pulse of voltage across T_1, circuit conditions are as shown in Figure 9A. Positive and negative signs indicate the polarity of voltage pulse E_{T_1} across T_1. At this instant, this pulse and the 600 volt supply are series aiding. Their total is applied to V_4 and C_9 in series. As indicated by the arrows, electrons flow from the supply negative terminal to the lower plate of C_9, and from the upper plate through V_4 and T_1 to the positive terminal of the 600 volt supply. This electron flow charges C_9 to the total of the applied voltages. E_{C_9} has the indicated polarity.

During the forward trace period, there is a low voltage across T_1 which makes the upper end of the winding negative as shown in Figure 9B. In series with this low voltage is the opposing 600 volt supply, and the aiding voltage, E_{C_9}. The algebraic sum of these voltages, applied to the series circuit C_{10}, V_5, and R_9, produces electron flow as indicated by the arrows. V_4 does not conduct at this time because the applied voltage makes its plate negative with respect to its cathode. However, conduction of V_5 charges C_{10} to the polarity shown.

During the next retrace interval when the upper end of the T_1 winding is positive, E_{T_1} and the 600 volt source, again series aiding, cause V_4 to conduct to recharge C_9. The electron flow is as explained for Figure 9A. At the same time, voltages $E_{C_{10}}$ and E_{T_1}, and the 600 volt source voltage are applied series aiding to the circuit containing R_{10}, V_6, and C_{11}. As shown in Figure 9C, electron flow in this circuit is produced and charges C_{11} to the total of the three applied voltages. V_5 does not conduct at this time because its cathode is more positive than its plate with respect to ground.

The action of Figure 9A charges C_9 to the pulse voltage E_{T_1} plus 600 volts. The action of Figure 9B charges C_{10} to E_{C_9} plus the low voltage across T_1 minus 600 volts, which is the same as the pulse voltage E_{T_1} plus the low voltage across T_1 during trace. Finally, the action of Figure 9C charges C_{11} to $E_{C_{10}}$ plus the pulse E_{T_1} plus 600 volts. That is, the voltage on C_{11}, the high voltage supply output, is equal to twice the pulse voltage plus the trace voltage across T_1 plus 600 volts. A typical $E_{C_{11}}$ voltage is 20 kv.

Referring to Figure 8, the voltage $E_{C_{11}}$ is applied between the anode and the cathode of picture tube V_8. Anode current consists of electron flow from the negative plate of C_{11} to the picture tube cathode, by means of the electron beam to the V_8 anode, and to the positive plate of C_{11}. This current tends to discharge C_{11}, but the charge is maintained by the high voltage supply circuit. The desired voltage regulation is provided by the voltage divider, R_{11} through R_{15}, and the triode, V_7. One type of tube designed for this purpose is the 6BD4GT. It is a low current, sharp cutoff tube, constructed to withstand the high voltage applied between its plate and cathode. In the normal operation of this tube, a blue glow is visible in the upper portion of its envelope. If its plate dissipation is near the rated maximum limit, the plate becomes dull red in color. These appearances do not indicate that the tube is defective.

In the circuit of Figure 8, the slider on R_{14} applies a positive voltage of about 356.5 volts to the grid of V_7. Thus, the grid is 8.5 volts negative with respect to the cathode. With this bias applied, the plate current is equal to about 600 microamperes.

In the picture tube, the beam current must increase to provide increases of picture brightness. Since the V_8 anode current is obtained from the high voltage supply capacitor C_{11}, the increased beam current discharges C_{11} at a faster than normal rate. As a result, the high voltage available at the supply output terminal is reduced. With lower voltage across C_{11}, the voltage of every point on the divider is lower also. Since the V_7 grid obtains its operating voltage from the slider on R_{14}, the grid becomes less positive. The cathode of V_7 remains constant at +365 volts, this voltage being obtained from the low voltage supply. Therefore, the action increases the grid-cathode bias, and decreases the V_7 plate current.

Like the picture tube anode current, the V_7 plate current is obtained from the high voltage supply. The circuit values are such that the increased bias decreases the V_7 plate current by approximately the same amount as the increase in V_8 anode current. Consequently, the total electron flow tending to discharge the high voltage supply capacitor C_{11} is about the same as it was before the picture tube beam current increased. Therefore, the high voltage output assumes a value almost equal to its original value.

In similar manner, a decrease in beam current allows the voltage across C_{11}, and the divider, to rise. The more positive grid makes V_7 conduct more heavily. The greater V_7 plate current makes up for the lower V_8 anode current, thus maintaining the proper charge on C_{11}. Thus, the proper high voltage is applied to the picture tube anode.

HIGH VOLTAGE SUPPLY TROUBLES

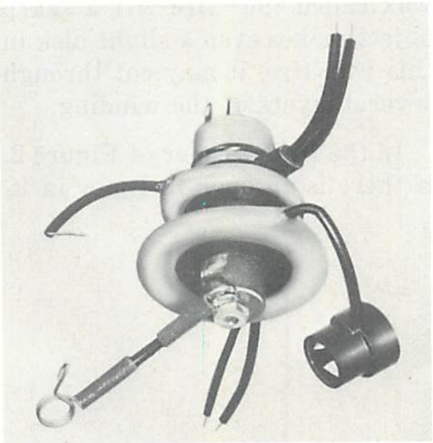
Defective tubes or components in the high voltage supply circuit, or closely associated circuits, almost always result in a decrease of the voltage applied to the anode of the picture tube. With lower anode voltage, the beam electrons move at lower speed from the gun to the screen to produce a picture with reduced brightness. Some defects, of course, reduce the high voltage supply output to zero, in which case there is no raster at all on the screen. However, normally these troubles do not interfere with the receiver sound channel. This fact provides a means of determining whether the low or high voltage supply is at fault. Low voltage supply troubles usually affect both sound and picture, while loss of brightness, or no raster, with proper sound, is the type of symptom produced by a defect in the high voltage supply.

In Figure 2, high voltage is applied from the positive plate of C_6 through R_4 to the anode of V_4. In turn, the voltage across C_6 is the result of the conduction of V_2 in the circuit containing C_6, the primary winding of T_1, and boost circuit capacitor C_2. An open in any of these components prevents current in this circuit, so that C_6 is not charged. Also, this capacitor cannot charge to a sufficient high voltage if it is leaky, or at all if it is open. The charging current is too small if the V_2 filament has reduced emission, or is zero if the filament is open. Sometimes this filament opens due to excessive filament current. When this is the case, replacing V_2 restores the high voltage only until the new tube burns out. That is, the cause of the trouble is still present.

The cause may be a too large drive voltage applied to the grid of V_1, resulting in the voltage produced across L_3 being too great. A second possible cause is that the resistance of R_2 may be too low to limit the V_2 filament current to the rated value, even when the L_3 voltage is correct. If the high voltage rectifier circuit is operating properly, the voltage across C_6 cannot be applied to the V_4 anode if R_4 is open, or the cap on the lead from R_4 is not making proper contact with the connector to the picture tube anode.

Since the V_2 plate current is produced by the positive pulses of voltage across the T_1 winding, and these pulses result from proper operation of the horizontal deflection circuit, defects in this circuit can result in either a decrease or complete loss of high voltage. First, the horizontal sweep oscillator must be producing the sweep voltage of proper amplitude. As explained previously, a defective oscillator tube, discharge tube, or circuit component can result in decreased or zero trapezoidal voltage output from the generator. If a sweep voltage is being produced, it must be applied with proper amplitude to the grid of the amplifier tube. This action depends upon the condition of the coupling circuit components, and setting of the drive control.

The sweep output circuit must produce the sawtooth current in the deflection coils, the boost voltage, and the high voltage flyback pulse, all of the proper amplitude, to correctly drive the high voltage rectifier circuit. Therefore, a defect in the output tube, output transformer, yoke, damper tube, width or linearity coils, or other components of this circuit can be the cause of reduced high voltage, or zero output from the high voltage supply.



Horizontal output transformers are constructed in a variety of forms. Although differing considerably in physical appearance, this flyback serves the same purposes as those shown previously.

Courtesy Chicago Standard Transformer Corp.

In the output transformer, frayed or poor quality insulation may permit a short to occur between turns of any one of the windings, or from one winding to another. Even one shorted turn permits greater than normal current in a coil, thus wasting energy that should be used to deflect the beam, or provide high voltage. Careless handling of the output transformer often causes a break in a winding or lead. A cold-soldered joint, where a lead connects to a winding terminal, may have the same effect as an open winding. In Figure 1, the winding L_1, called the tertiary, sometimes is wound with No. 40 wire which has approximately the thickness of a human hair. This winding is covered with a thin coating of wax called the "tire". If a sharp object makes even a slight nick in this wax tire, it may cut through several layers of the winding.

In the transformer of Figure 2, if there is an open in L_2, or in L_1 between the tap and the lower end, there is no deflection, boost voltage, or high voltage produced. An open above the tap on L_1 does not prevent production of boost voltage or deflection, but usually there is no high voltage. However, with this trouble, high voltage is produced in some cases due to the inductive coupling of the h-f pulse through the transformer winding.

It has been mentioned that a special frequency control circuit is employed to keep the horizontal sweep oscillator in synchronism. A number of types of such control circuits have been devised. The next lesson describes these circuits and their operation.

* * *

STUDENT NOTES

STUDENT NOTES

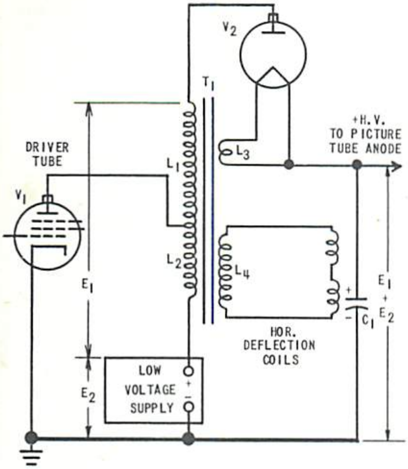


FIGURE 1

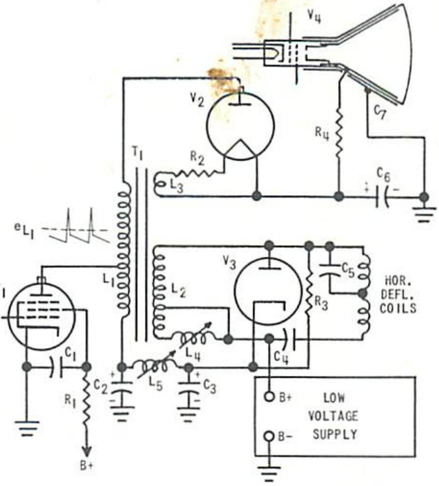


FIGURE 2

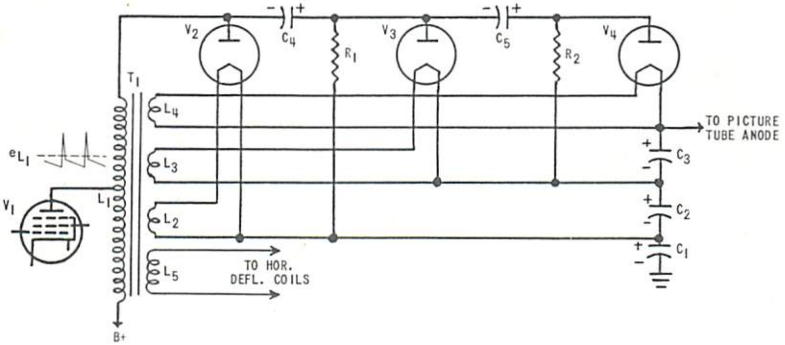


FIGURE 3

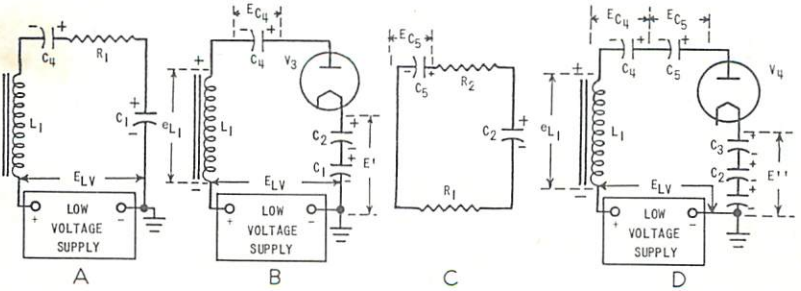


FIGURE 4

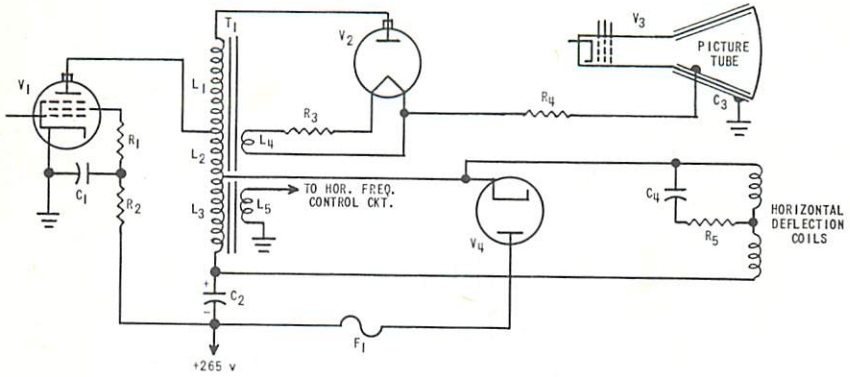


FIGURE 5

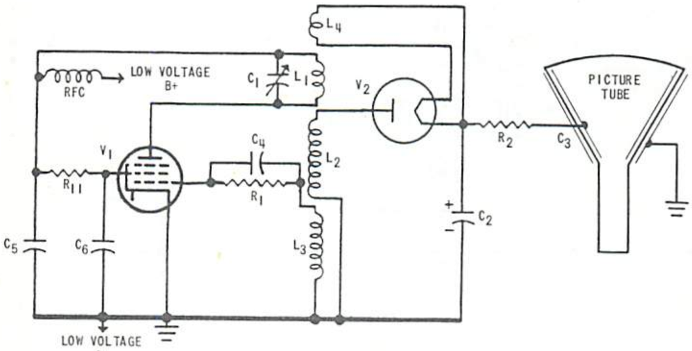


FIGURE 6

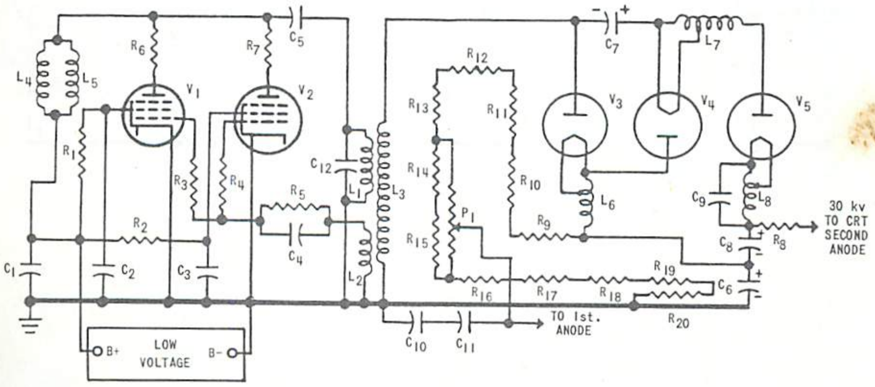


FIGURE 7

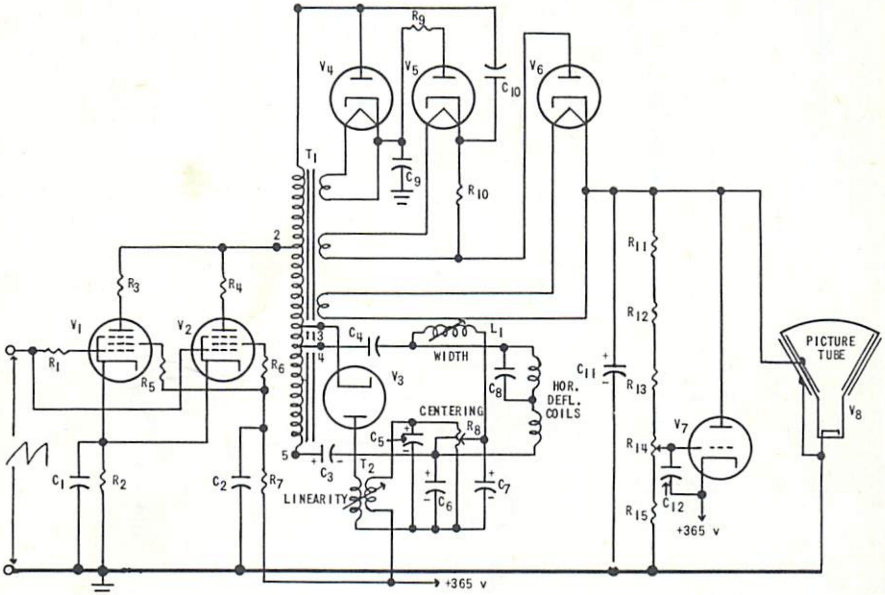


FIGURE 8

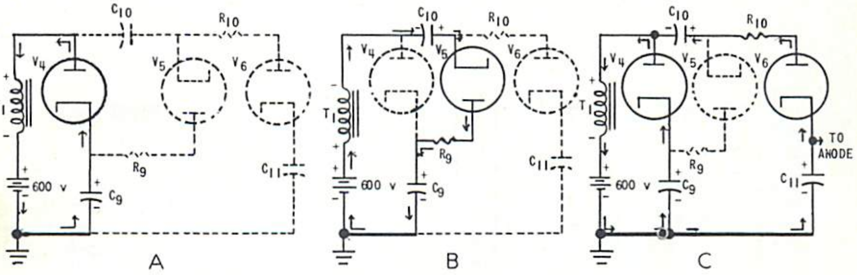


FIGURE 9

FROM OUR *Director's* NOTEBOOK

POSITIVE THINKERS

The world contains two kinds of people, negative thinkers and positive thinkers—those who think failure and those who think success. Negative thinkers are afraid to venture anything for fear something might happen. The fellow who, when confronted with a problem, runs to someone else with it because he "might make a mistake." The do-nothings, the nervous wrecks, the failures —these are negative thinkers.

The positive thinkers are happier, more alive, more active, more adventuresome. They get things done. They make mistakes, they're bound to. But as long as their batting average is within reason, as long as what they do makes sense, they're more often applauded than criticized. And they try not to waste their time in fruitless efforts.

Yours for success,

W. C. DeVry

DIRECTOR

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